PROCEEDINGS

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KNOWLEDGE BASED SYSTEMS FOR PATTERN RECOGNITION ALLOW AUTOMATED PROCESS STABILIZATION IN LASER ETCHING

Mohammad Mashi, Christoph Ament

Department of System Analysis, Faculty of Computer Science and Automation,
Technical University of Ilmenau, Germany
mohammad.mashi@tu-ilmenau.de

ABSTRACT

Laser etching is a novel surface processing technique for metallic materials. Especially rigid materials as used for micro tools can be processed with this method. This process is controlled by several parameters, e.g. laser beam power, laser beam focus, material feed, and flow of surrounding reactant, which depend on environmental conditions as temperature. Therefore, the process is very difficult to control, which hinders the introduction of this method into an industrial application.

In our contribution a pattern recognition approach is presented, which helps stabilizing process quality: For process calibration a material probe with a number of grooves with fixed sets of parameters is produced. Then, the probe surface is optically measured and the obtained data is provided to the algorithm. It is able to localize the grooves automatically. For this purpose, two methods of machine learning are deployed. The First is nearest neighbour method, the second is clustering. Due to noise it is difficult to differentiate between grooves and surface. A knowledge based system is used for this decision. The algorithm allows adaptive behaviour to different probe topologies. After groove recognition, depth and width of the groove are identified. These parameters can be provided to the automated machine calibration.

Index Terms - Artificial Intelligence, Machine Learning (ML), Knowledge Based System (Data Mining) and Laser etching

1. INTRODUCTION

1.1. **Process of laser etching**

Laser-chemical etching is a novel processing technology for micro cold forming and structuring of metal workpieces [1,2]. It allows the micro machining of surfaces without a significant heat input. Figure 1 shows the laser system and how the process of laser etching is done experimentally. The material probe is moved on a xy-table while it is processed by the laser beam, which is fixed on the top of the probe surface. The probe is completely covered by a reactive fluid.

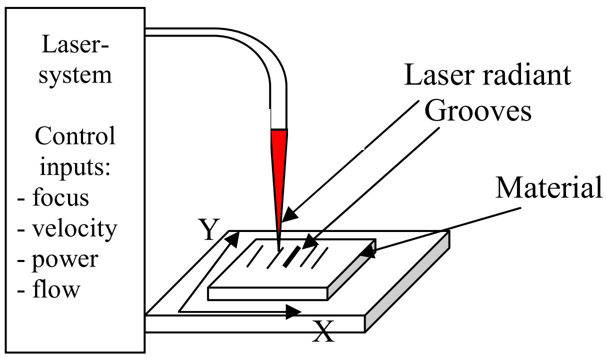


Figure 1: The laser system and the process of laser etching.

1.2. **Control of laser etching**

The major drawback that impedes the industrial application of laser-chemical etching is the process control: As shown in figure 1 there are four control inputs: The laser focus and power, the feed velocity as well as the flow rate of the chemical. Their impact to the process is hard to model, and it might be disturbed by further influences like the temperature of the reactive fluid. Process capability cannot directly be guaranteed.

Therefore, we suggest a calibration procedure that can be applied e.g. once a day during the start-up of the system. On a probe surface a predefined pattern of grooves is processed (see Figure 1). Each groove is processed with a different set of control inputs. Afterwards, the depth and width of grooves will be measured. These parameters will be used for process identification. This calibration procedure has to be carried out in an automated way (see figure 2).

In this contribution machine learning methods for the feature extraction within the calibration method is presented. We explain the methods of finding the grooves in the following section. The third section provides the results and the fourth discusses the implementation issues. We conclude with suggested fields of application.

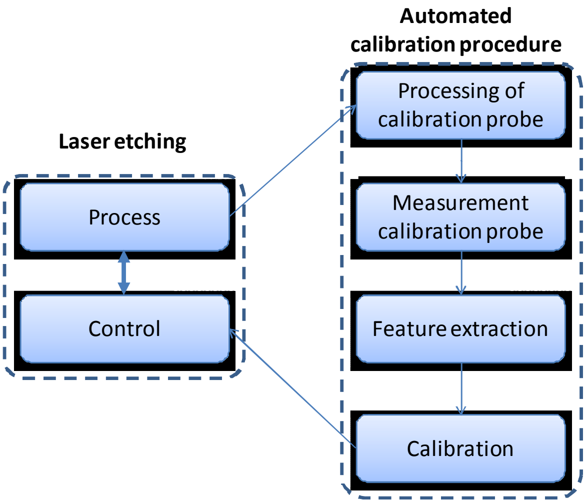


Figure 2: The automated calibration procedure is based on a processed calibration probe.

2. METHODS

After etching we receive the calibration probe and measure it using a stylus instrument with an optical autofocus sensor [1]. The data is stored into a specific file format (Perthometer Concept Datei, PCD).
It represents the surface of the etched material. This is illustrated in figure 3.

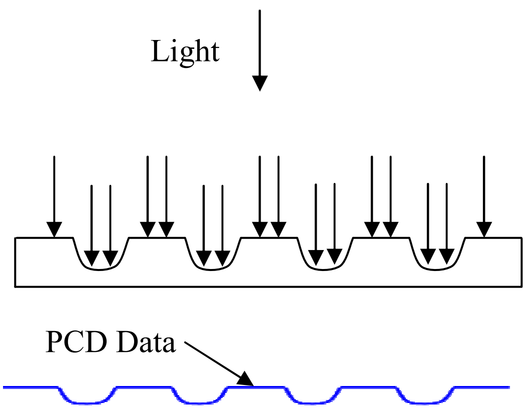


Figure 3: Optical measurement.

2.1. Data preparation

There may be deviation in the position of the probe as shown in figure 4, which has to be corrected automatically.

The first step by the program is to relate the surface to angle $\alpha=0$.

Next is the preparing step, which tries to find the coordinates of all points, which are located in grooves. Grooves are detected, if the vertical coordinate of a point is below a threshold value as shown in figure 5a.
The coordinates of all points which satisfy this condition are stored into a list. It represents a classification of all points into "surface" or "groove", which can be illustrated in figure 5b. It shows the top view of the probe and the location of the grooves.

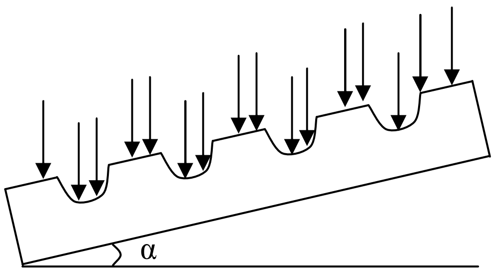


Figure 4: Optical measurement with angle α.

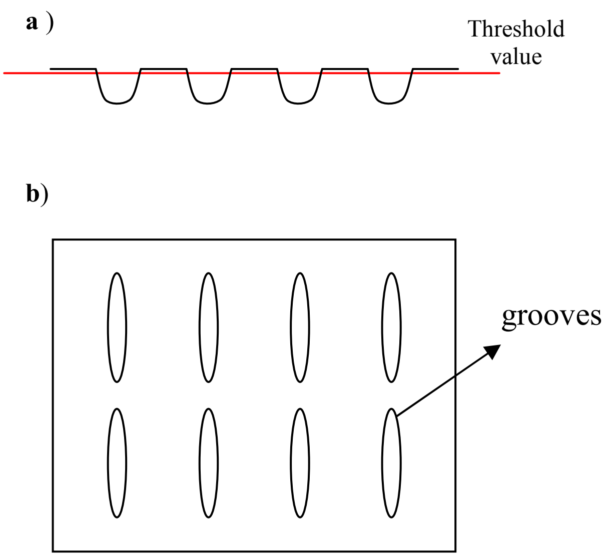


Figure 5: a) preparing step with threshold value. **b)** The coordinates of the grooves.

Significant problems arise with uneven surface. Figure 6a show the influence of a stoop.

It is impossible to find a single value as threshold to determine which points belong to groove and which do not. Therefore, we need to implement the detection in two steps. The first one is to detect an area of grooves. It shows in figure 6b.

We need here the new threshold that the old threshold in the surface value. The new threshold can be determined with this equation (1)

$$K_1 = 0.2*K \qquad (1)$$

Where the K is the deepest point from surface value and K_1 is the value of the new threshold. It is shown in figure 6b.

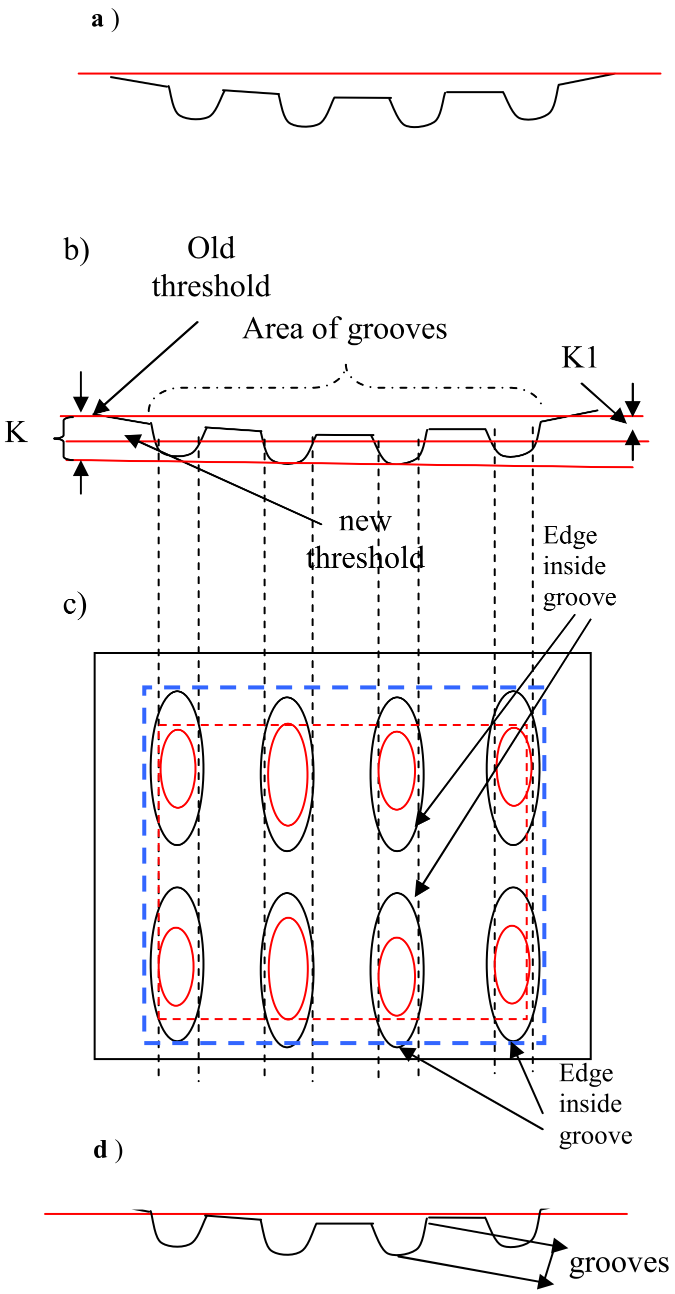


Figure 6: a) stoop in surface.**B)** determine the area. **c)** area of the grooves d) grooves

The program determines all points below the threshold K1. These points from an area where grooves are located. It is shown in figure 6c where the small ovals express these points and the small rectangle with solid line are part of the area of grooves. And the big solid rectangle express the all points of grooves. Therefore, in the second step the program tries to reach small rectangle to large rectangle. The depicted small dashed rectangle is constructed from all small grooves. Next, by computing the correct dimensions of all grooves (the bigger solid ovals) individually, the correct area of grooves is computed (bigger dashed rectangle).
After that we move to the next pace from program to determine every groove along as shown in figure 6d.

This adaption enables us to correctly identify all grooves with their according properties.

2.2. **Feature detection**
All points that are classified as "groove" are processed in the following three steps:

1. This data is processed with a machine learning step. The "Nearest Neighbour method" computes the distances between all points that are below a threshold value [3,4]. But in this paper we have developed an alternate approach. Instead of computing the distances between all points in all directions, the program begin in X direction and then continues in Y direction. This is shown in figures 7a and 7b.This method based on the equations (2):

$$D_x = |x_2 - x_1| \qquad (2)$$
$$D_y = |y_2 - y_1|$$

D_x and D_y are the distances in X and Y direction, respectively and x_2 and x_1 are two points in direction X and y_2 and y_1 are two point in direction Y. First it computes D_x then clusters the point in small groups as shown in figure 7a. In the next step this process is repeated for these small groups in the direction of the Y axis to find the big groups, which are grooves. This is illustrated in figures 7 b, c.

One can clearly see here that first the distance between the points in x direction is calculated with the Nearest-Neighbour-Method. Then, clustering is used to find small groups. This is then repeated again for the small groups to find the grooves. Thus, the method is used for both steps.

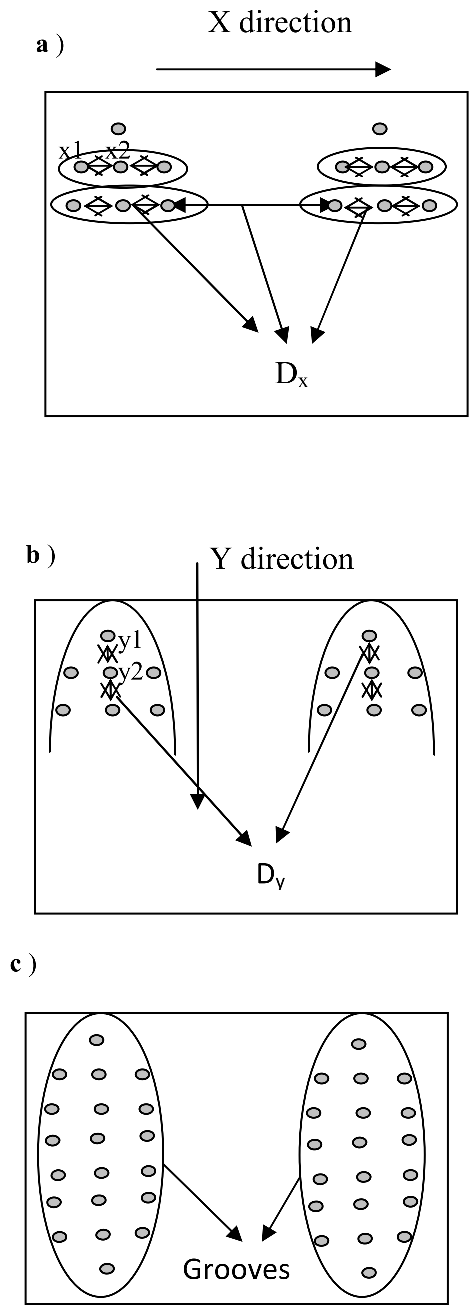


Figure 7: a) Nearest-Neighbour-Method for D_x and clustering. **B)** Nearest-Neighbour-Method for D_y and clustering. **c)** Grooves

The clustering [3,4] is again based on finding the points with the smallest distance. It is sown in figure 8. As explained earlier, this must be done after the first step. The line shows the so determined edge of the groves.

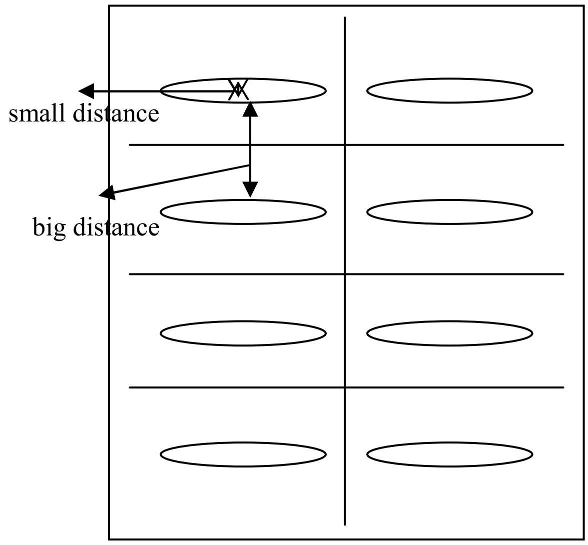


Figure 8: Method of clustering.

2. The surface is not perfectly smooth. Small defects such as holes might wrongly be detected as grooves. Therefore, a filter is needed to distinguish between grooves and surface. Such a filter can be implemented as a knowledge based system which relies on only a few rules. For example we take the average value of the length of all grooves and holes (noise). It can create the information as rules for (KBS) than it can be decided. If the length of every groove is bigger than the average, it is assigned as a groove, otherwise it is not. It is shows in figure 9.

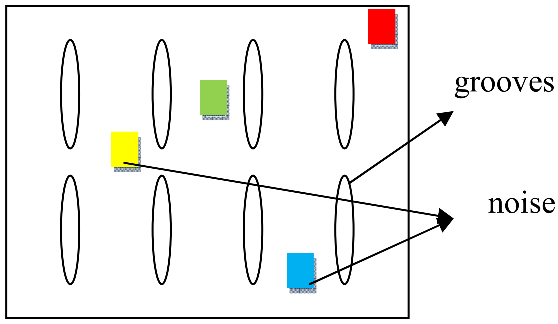


Figure 9: white colure is the grooves but other are noise

The property of grooves can form it in rules if-then in KBS [4,5].

3. After grooves have been identified their depth and width is calculated. This is again done by using the "Nearest Neighbour method". For depth it is performed between the highest and lowest points in the groove. For width the points farthest apart are used. It be discribed in figure 10

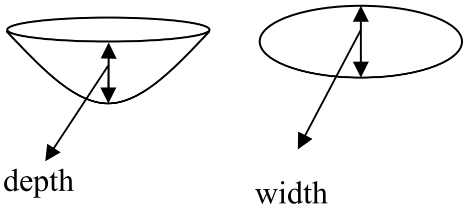


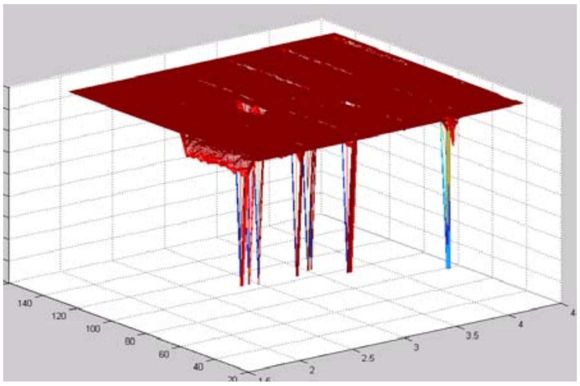
Figure 10: computing depth and width

Those steps describe the implementation of the clustering method to determine the position on grooves together with their depth and width.

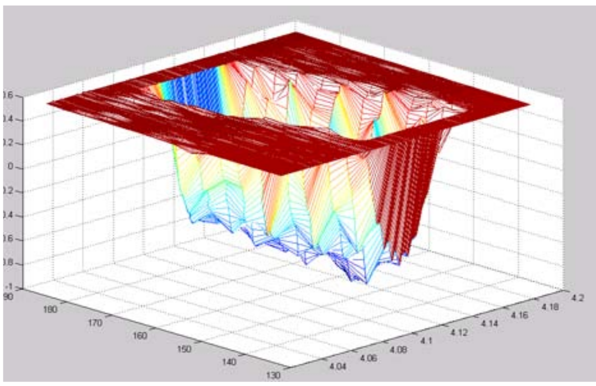
3. RESULTS

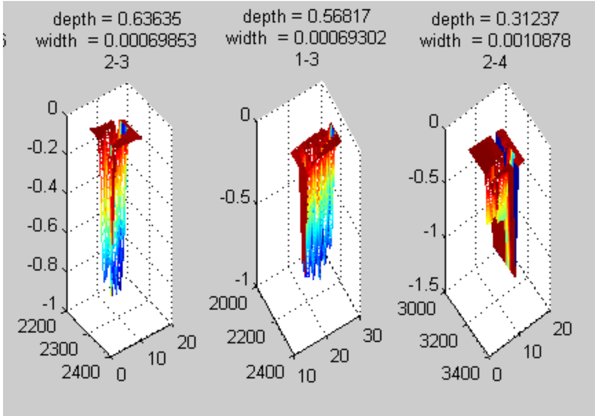
The algorithm from the above section was programmed in Matlab. Figure 11a, b, and c show of results.

a)



b)





c)

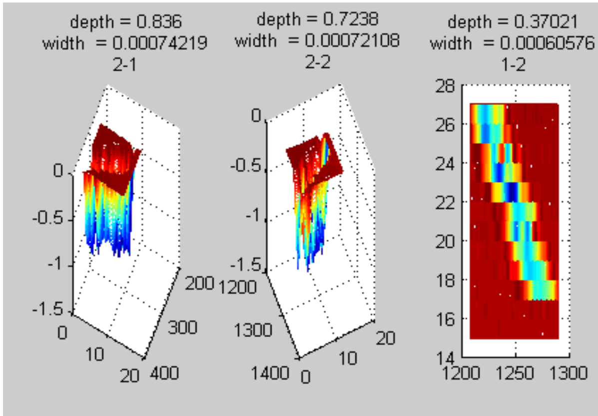


Figure 11: a) Original surface with grooves. b)one groove. **c**) Results of methods of ML with width and depth

Figure 11a illustrates the original surface of material in matlab. Figure 10b shows the form of single groove.
The target results are provided in figure 11c first and second line the depth and width of all grooves and third line is the order of every groove and the form of grooves in all directions. The results can be written in Excel as table.

The results are shown in table 1

Grooves No.	Grooves location	Depth (µm)	Width (µm)
1	1-2	0.3702	0.0006
2	1-3	0.5681	0.0007
3	1-4	0.6074	0.0008
4	1-5	0.8502	0.0008
5	1-6	0.9714	0.0009
6	2-1	0.8360	0.0007
7	2-2	0.6681	0.0006
8	2-3	0.5878	0.0006
9	2-4	0.2947	0.0010
10	2-5	0.3130	0.0006
11	2-6	0.2116	0.0006

Table 1: results of the program

It shows the location of the grooves as is displayed in figure 12. The measurements are in µm.

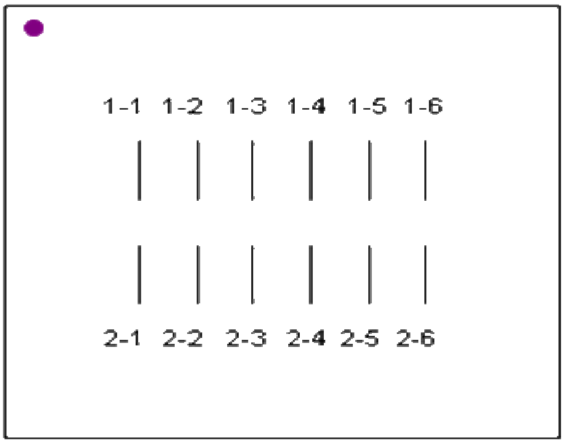


Figure 12: location of grooves on the surface material

4. DISCUSSION

With correct vertical alignment no problems occur. However, misalignment as shown in figure 13 may lead to errors.

Due to the nature of the measurement method some areas will be affected by shadowing effects. This shows in figure 13.

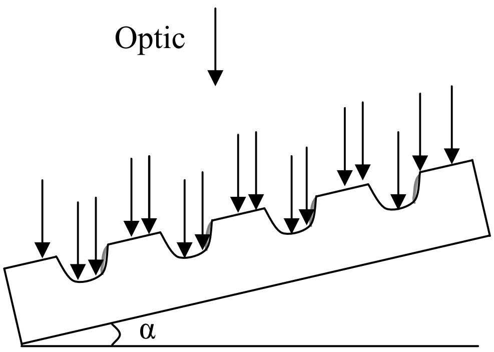


Figure 13: Optical measurement with angle α.

These areas, which are marked with grey color, will then result in a wrong calculation of both the width and the depth of the groove. A rotation of the surface during the process can compensate for the shadowed areas but will still result in errors when computing depth and width.

It is not possible to compare my result with real data because I cannot get the real data. But in this paper three problems are solved. One can use them in other fields. As we explain this in the conclusion.

5 . CONCLUSION

We presented a concept of measuring of machine learning. The goal of this method is to measure the depth and width of those grooves. Moreover, an extended analysis of those grooves including e.g. their arrangement, centre or areas can be included. Its use can be adapted to other fields of interest, such as image processing, vision and satellite photos. Also, the computed data can help to asses and improve the etching process itself by implementing it in a closed-loop control circuit.

6. REFERENCES

[1] P. Cuypers, A. von Freyberg, G. Goch, A. Stephen, F. Vollertsen: Parameter and Path Planning for a Laser-Chemical Production of Micro-Forming Dies (in German), Technisches Messen 77 (2010), p. 229–236.

[2] Removal rate model for laser chemical micro etching Andreas Stephen, Ralf Walther*, Frank Vollersten BIAS GmbH, Bremen, Germany June (2009)

[3] Grundkurs künstliche Intelligenz : Eine praxisorientierte Einführung / Wolfgang Ertel. (2008)

[4] Maschinelles Lernen und wissensbasierte Systeme: systematische Einführung mit Praxisorientierten Fallstudien / J. Herrmann (1997)

[5] Methoden wissensbasierter Systeme : Grundlagen, Algorithmen, Anwendungen 4. Auflage / C. Beierle , G. Kern-Isberner (2008)